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U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

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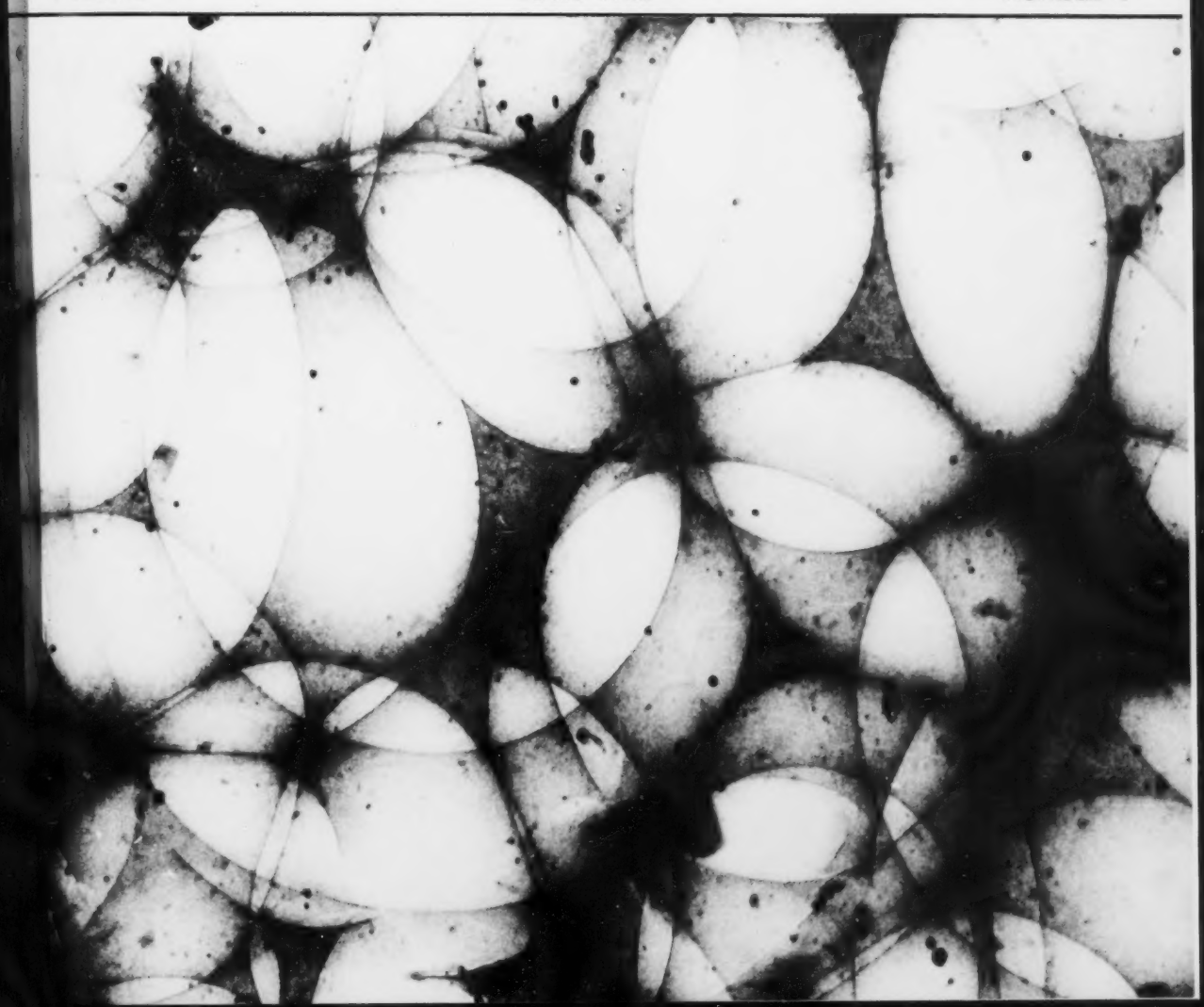

U.S. DEPARTMENT OF COMMERCE — LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS — A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

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COVER: Point-projection microradiograph of a glass foam material. During an NBS survey of available instrumentation and techniques that might be adapted to the study of polymer structure, it was found that point-projection microradiography often reveals detail difficult or impossible to obtain with any other technique. (See page 55.)

Polymers Studied with Point-Projection Microradiography

AN NBS SURVEY of available instrumentation and techniques that might be adapted to the study of polymer structure has shown that point-projection microradiography gives excellent results.[1] In fact, it sometimes reveals detail impossible to obtain in any other way.

S. B. Newman of the polymer characterization laboratory used this technique to obtain microradiographs of foams, laminates, fibers, and fabrics. These microradiographs provide a ready means for correlating anomalies in physical properties, such as tensile strength, with anisotropic microstructures. They are also valuable in the detection of origins of failure in opaque structures before ultimate fracturing occurs. Use of the point-projection technique with polyphase systems permits observation and control of the dispersed phase. When one phase is responsible for strength or reinforcement, the technique can be used to characterize the optimum relation of the phases.

Point-projection X-ray microscopy, because of its ability to demonstrate failures or defects before they are otherwise visible, should prove to be a useful technique for improving existing polymeric materials and developing new ones. It may also help manufacturers to avoid the distribution of products that may prove unsatisfactory in service.

During the Bureau's survey, three techniques for producing enlarged images of microscopic structures through the absorption or scattering of X-rays were considered. These were contact, reflection, and point-projection microradiography.

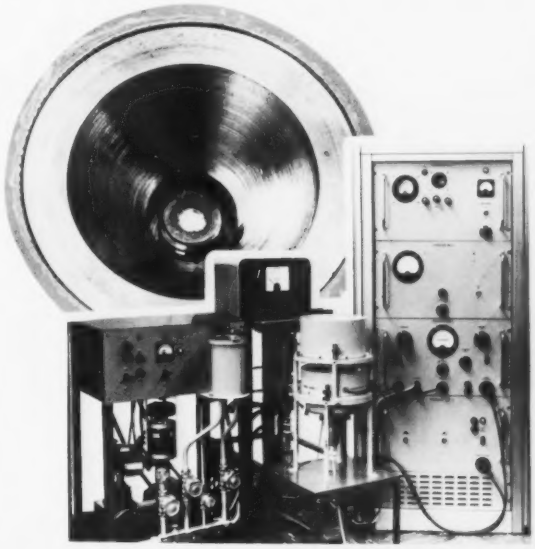
In the contact method, the specimen is placed in close proximity to a photographic plate and exposed to an X-ray beam. Although widely applied in biological fields, this method was found to be not readily adaptable to the study of polymeric materials.

A reflection microradiograph, obtained by the second technique, is produced by the total reflection of X-rays at glancing incidence from polished concave mirrors. Because of serious optical problems, the reflection X-ray microscope remains in the developmental stage and it was decided not to try to adapt this instrument to polymer studies.

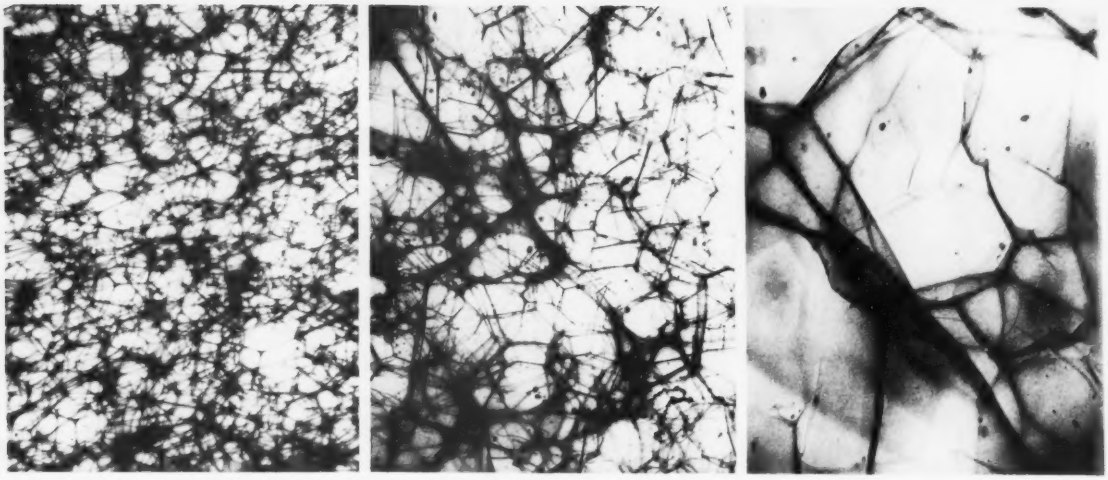
In the point-projection method chosen for the study, an enlarged image is formed when the object is placed close to a point source of X-rays. The magnification is then the ratio of source-image to source-object distance. An X-ray microscope is used to provide the point source of X-rays. The lenses of the microscope produce a demagnified image of an electron source on a thin metal target which acts as the vacuum seal in the pole piece of the objective lens. The electrons strike one side of the target, causing it to emit X-rays in a small area on the opposite side to form the point source.

For almost all the NBS work, a two-lens electromagnetic X-ray microscope was employed. The particular specimen under study was placed directly on the center of the target. The elements that make up most commercial polymers are of low atomic numbers; hence, relatively long wavelength X-rays were necessary to produce adequate contrast in the microradiographs. For this reason, either aluminum or copper targets were used, depending on the thickness and X-ray absorption of the specimen.

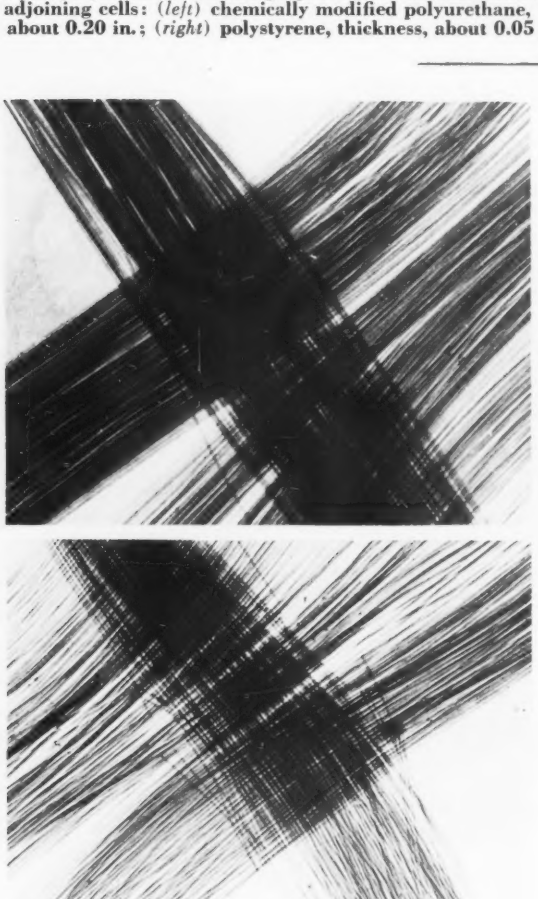
Although the point-projection technique does not readily lend itself to precise measurement of linear dimensions, it is extremely useful in the delineation of shapes of structures and their distribution in a matrix.



An overall view of the equipment used to evaluate the application of point-projection microradiography to the study of polymeric materials. The lenses and gun of the two-lens electromagnetic X-ray microscope are mounted on the stand in the foreground. Vacuum pumps, gages, and controls are in the cabinet at left. Electrical high-tension, bias, and filament supplies are in the rack at the right. The lens coils are supplied by storage cells. Background shows close-up view of the pole piece and the target of the objective lens of the microscope.



Point-projection microradiographs of various commercial foams. The darkest lines show where a cell surface meets adjoining cells: (*left*) chemically modified polyurethane, thickness, about 0.15 in.; (*center*) polystyrene, thickness, about 0.20 in.; (*right*) polystyrene, thickness, about 0.05 in.



Point-projection microradiographs of a glass-fiber-reinforced paper tape before and after repeated flexing. (*Top*) Before flexing, the reinforcing fibers in the paper sandwich can be seen. Paper fibers and air bubbles in the adhesive interlayer are faintly visible. (*Bottom*) After repeated flexing, damage to the glass fibers in the yarn normal to the flexing plane is easily detected. Fibers parallel to the flex appear to be undamaged.

Damage or discontinuity in the structure, such as cell-wall breaks, is revealed. Particulate matter or additives, such as pigments which are scattered through the cell walls or in the cells, are resolved.

Applications of the Technique

Foams: Foamed plastics are widely used as insulation, structural elements, shock absorbers, sponges, and in various other ways. A number of different polymers have been used to produce the foams now commercially available. These foams vary widely in microstructural characteristics, but the differences must be observed in the light microscope either by reflected light on a cut surface or in a thin section cut from the bulk. In such specimens, deformation due to cutting may be considerable; and in thin sections, whole cells may be missing or comparatively scarce.

The X-ray microscope, by resolving detail in a relatively thick section, permits a more accurate evaluation of the structure. The image obtained is essentially a two-dimensional pattern showing many of these cells superimposed upon one another.

A number of microporous plastics, such as polyethylenes and vinyls, were also examined with soft radiation. Many overlapping, well-demarcated areas of relatively high X-ray absorption were revealed by radiation from an aluminum target. The contrast, even with this

soft radiation, was quite low. Pathways made through the materials by a substance opaque to X-rays could easily be recorded.

Laminates: Several attempts were made to examine the glass-resin interface in a number of polyester laminates. Unfortunately, the thickness of the glass-free resinous surface layer and the effective thickness of the specimen resulting from its undulating surface increased the target-to-specimen distance to such an extent that high-resolution examination was not possible. Special preparations of resin and glass would probably be required for this type of investigation.

It was found, however, that the X-ray microscope can resolve considerable detail in large areas of laminated materials. For example, when a glass-fiber-reinforced paper tape was examined before and after flexing, damage to the glass fibers in the yarn normal to the flexing plane was easily detected and evaluated. Fibers parallel to the flex apparently were undamaged.

Asphaltic materials, in general, present a problem in microscopy which is uniquely susceptible to solution by X-ray techniques. Stratification in the asphalt as well as the location of the reinforcing are clearly revealed. Such detail would be difficult or impossible to demonstrate by other methods.

Fibers and fabrics: Since the transmission of even the long-wavelength X-ray spectrum by most polymeric fibers is extremely high, this type of examination reveals only the spatial distribution of fiber elements. However, low-magnification studies of fabrics may also provide valuable data. Contrast between an elastomer and cellulose in a fabric is sufficiently high that deformation and stress distribution among the elements in the structure can be observed.

The low X-ray absorption of most fibers can be advantageous when the object of the examination is the detection of inclusions or adsorbed particles. Natural cellulose fibers of bast or leaf origin often contain crystals of calcium oxalate or siliceous structures, such as those in abaca, ramie, and jute. While it is difficult to detect these in the light microscope without resorting to microincineration, the inclusions are easily resolved in their original orientation with X-ray microscopy. The light microscope would require an immersion liquid for equivalent resolution. If the immersion liquid were used, the bond between the substrate and the particles would be stressed.

[1] *For further information, see* X-ray microscopy of polymers by point projection, *by Sanford B. Newman, Modern Plastics* **40**, *No. 7, 165–179 (1963).*

1963 Cryogenic Engineering Conference

THE UNIVERSITY of Colorado and the Bureau will act as joint hosts for the 1963 Cryogenic Engineering Conference to be held in Boulder, Colorado on August 19, 20, and 21. Preregistration information and a copy of the program will be available about the middle of July 1963.

Papers on the technical aspects of cryogenic engineering in the area below 150 °K are now being solicited for presentation at the 1963 Conference. The deadline for *both* abstract (not over 200 words) and a preliminary manuscript is May 1, 1963. Preliminary manuscripts should include final data if possible and must be detailed sufficiently to facilitate careful evaluation by the Conference Committee and its editorial board. Papers which do not meet the standards of the Conference will not be accepted for presentation.

Manuscripts should be submitted to:

K. D. Timmerhaus, Secretary
Cryogenic Engineering Conference
Chemical Engineering Department
University of Colorado
Boulder, Colorado

This year's Conference will emphasize the exchange of information and ideas by advantageous scheduling of numerous small seminars and the spotlighting of a special session on basic review papers. The general program itself will not be directed toward any particular theme and the Conference Committee welcomes and encourages papers on all fundamental Cryogenic subjects. As at previous conferences, the Committee will invite papers from recognized authorities for the initial session and to begin various other technical sessions. Based on past and current interests in the field, session topics may include physical equilibria, cryopumping, properties, applications, heat transfer, fluid transfer phenomena, and insulation. The Committee intends to continue the reporter system for the mechanical properties session and may extend it to physical equilibria this year if feasible. In this system, two reporters clarify data trends and experimental techniques and present a cohesive résumé of contributed papers in the subject area. Following the summary presentation, individual authors are given an opportunity for comment and rebuttal and are invited to participate in the ensuing discussion period. With the anticipated variety of contributed papers and emphasis on seminars, this year's program will require a full three days.

Papers presented at the 1963 Conference will be published in Volume 9 of the *Advances in Cryogenic Engineering*, provided that the final manuscripts are acceptable. Volume 8, the *Proceedings* of the 1962 Conference, will be available the latter part of April 1963. Delegates who attended this Conference will automatically receive their copy of Volume 8 when it becomes available.

HIGH-PURITY CRYSTALS GROWN FROM SOLUTION

AN EFFICIENT, reproducible method for growing large single crystals from solution has been developed at NBS.[1] Crystals grown by this method are homogeneous in physical structure and exceptionally pure. They may be used for reference standards in chemical reactions, for calibrating instruments, and as specimens for the precise measurement of physical properties of solid-state materials.

The growth of crystals from solution requires that the solution remain supersaturated even though dissolved solute is removed as it is deposited on the crystal faces. Thermal and mechanical shock must be avoided, and the crystal-growing bath must be protected from contamination and from extraneous crystal growth. Equipment and procedures meeting these requirements were designed by J. L. Torgesen, A. T. Horton, and C. P. Saylor of the analytical and inorganic chemistry laboratory as part of a broad program to investigate crystallization phenomena.

Preliminary experiments were conducted with materials of simple crystal habit which grow readily in single crystal form. Many crystal species have since been grown. Although some changes are required as the nature of the solute is changed, the equipment and procedure for growing most of the crystals are similar.

Crystal Growth Assembly

The crystal-growing solution is contained in a 4½-gal cylindrical glass jar. A jar cover of methyl methacrylate resin supports the stirring mechanism and the temperature-indicating and control devices. The seed crystals are held on glass pins situated near the ends of the arms of a "crystal tree" or "spider" fitted to the jar and attached to the shaft of the stirring mechanism. This tree consists of a central glass rod or axis onto which are fastened three rows of four radially symmetrical glass rods, to accommodate a total of twelve crystals. A jig is used for fusing twin glass pins near the ends of the arms and for drilling small holes in the seed crystals. Trouble-free, even interchangeable mounting and easy harvesting of the crystals are thus achieved. Thin sleeves of polytetrafluoroethylene cover the pins and prevent adherence between the crystal and its supporting pins.

Crystal growth is initiated by securing the lid (with the apparatus and seed crystals) to the jar containing the desired solution. With this equipment in place and operating continuously, the seed crystals gradually begin to grow and are ready for harvest in a number of weeks.

In order that all surfaces of the growing crystal may be washed approximately equally with solution to promote uniform growth, a rack-and-pinion mechanism is provided for rotating the crystal tree in alternate directions. The rack, moved back and forth by an eccentric attached to the shaft of a slow-speed motor, meshes with the pinion gear fixed to the tree shaft. With this arrangement, the glass crystal tree rotates at a maximum speed of approximately 25 rpm, with four rotations between changes in direction. Temperature and concentration of the solution are kept uniform by constant mixing. Rectangular glass plates, hinged on the arms of the tree, change position (depending on the direction of rotation) and promote vertical transfer of the solution in the jar.

Crystal Bath Temperature Control

Inclusions or other imperfections in a growing crystal may result from interrupted or accelerated crystal growth rates caused by temperature fluctuations or finite temperature changes of a few hundredths of a degree. To minimize this effect, a uniform degree of supersaturation is maintained by closely controlling and continuously decreasing the temperature of the bath.

The bath temperature is partially maintained (near 50 °C) by banks of small (15-w) lamps located within a frame on which the jar rests. Heat thus provided from below helps to prevent extraneous crystals from growing on the bottom of the tank. Heat is also supplied to the bath through two immersion-type finger

Illustration, above: **J. L. Torgesen inspects crystals of ammonium dihydrogen phosphate in a crystal growing bath. The zippered insulation jacket is removed only during inspection periods; the temperature-control mechanism is in the background.**

heaters controlled by a mechanism which time modulates the electrical energy supplied to the finger heaters proportionally to any departure from a particular control point.

The system controls the bath temperature to ±0.002 °C, but permits the temperature to decrease continuously at any chosen rate between 0 and 0.15 °C per day in steps of approximately 0.015 °C per day. Automatic controls permit such operation for a maximum of 100 days without manual adjustment.

Concentration Measured by Electrolytic Conductance

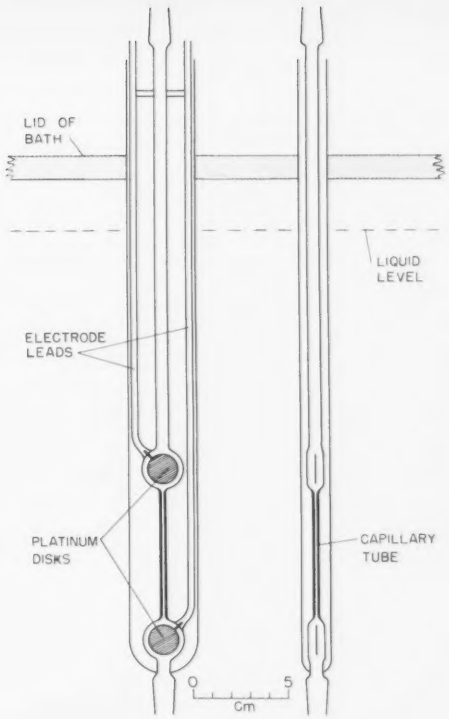
Since the rate of growth on individual crystal faces depends on the supersaturation of the parent solution, a means of measuring the solution concentration is imperative in studies where reproducible growth conditions are required. The electrolytic conductance of ionic solutions has been found to be a precise and sensitive measure of the concentration of these solutions at a given temperature in the saturation region. A special type of immersion conductance cell was therefore designed and constructed by the Bureau for determining the concentration of crystal-growing baths.

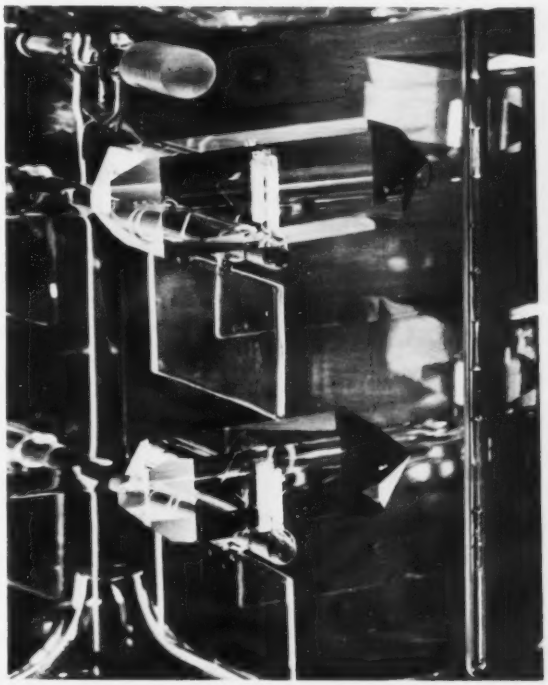
The cell is immersed in the crystal bath and becomes an integral part of the crystal-growth assembly. It fills with solution automatically and may be flushed with fresh solution quickly and easily by applying mild gas pressure at the top. The electrodes are platinum disks, approximately 1.5 cm in diameter, centrally located in compartments separated by capillary tubing. Capillary dimensions were chosen to give measured cell impedances of convenient range. The cell proper is enclosed in an oval glass envelope filled with a medium of low dielectric to inhibit disturbing electrical effects.

Conductivity measurements are made in conventional fashion at audiofrequencies with an a-c Wheatstone bridge circuit. The concentration of a solution, and its degree of saturation, can then be found with established conductance-concentration-temperature data.[2]

[1] Equipment for single crystal growth from aqueous solution, *by J. L. Torgesen, A. T. Horton, and C. P. Saylor, J. Research NBS* **67C** *(Eng. & Instr.), No. 1, 25–32 (Jan.–Mar. 1963).*

[2] Electrolytic conductance of ammonium dihydrogen phosphate solutions in the saturation region, *by J. L. Torgesen and A. T. Horton, J. Phys. Chem.* **67,** *376–381 (1963).*





Above: **Immersion conductance cell** *(front view at left, side view at right)* **provides a means for accurately measuring the concentration of crystal growing solutions. The conductivity of the solution in the capillary tube is measured and is converted to terms of concentration by predetermined conductance-concentration-temperature relationships.** *Below:* **Ammonium dihydrogen phosphate crystals growing from solution. The outline of the seed crystal is visible near the center of the crystals. Rectangular glass plates assist in stirring the solution as the mechanism rotates. The platinum sensing coil** *(right)* **monitors and controls the solution temperature within close tolerances.**

STANDARD MATERIALS

Mrs. V. I. Burns holds a reflected-light photographic exposure meter against a "sandwich" filter which converts the color temperature of the light source (*left*) **to 4700 °K, the temperature now used in the calibration of such meters. The square glass filter on the photometric bar** (*lower center*) **also converts the source color temperature to 4700 °K for the calibration of incident-light meters.**

Standards for Calibrating Photographic Exposure Meters

IN RESPONSE to requests from the photographic industry, the Bureau has initiated a program to supply standards for use in calibrating photographic exposure meters of the photoelectric type.[1] The standards consist of sets of two filters, one of blue glass for calibrating incident-light meters, and the other, a diffusing sandwich consisting of both a Plexiglas diffuser and a blue glass, for calibrating reflected-light meters. Designed in cooperation with the American Standards Association (ASA) which had proposed specifications for such standards, the filters permit calibration of exposure meters that are intended for both indoor and outdoor use.

In an earlier ASA procedure established for the industrial calibration of photographic exposure meters, the effective light-source color temperature specified was about 2850 °K, that is, the color temperature of a general-purpose incandescent lamp. However, when meters calibrated at this color temperature were used under natural daylight conditions, large discrepancies were sometimes noted in meter exposure values. Recent ASA studies showed that calibrations made at a color temperature of about 4700 °K would eliminate these discrepancies. The Bureau therefore undertook an investigation to obtain filter standards that would increase color temperature for meter calibrations to this value, and to calibrate such standards for industrial use. The work was performed by Mrs. V. I. Burns and R. P. Teele of the photometry laboratory.

The blue filters, 6½ in. square, were calibrated for luminous transmittance by means of a photometer in which a 500-w projection lamp (color temperature 2854 °K) was used. The value for luminous transmittance of each filter thus found is given in a calibration report accompanying the filter. This value is used to compute the illumination at 4700 °K of the light transmitted by the blue filter in incident-light meter calibrations.

The diffusing sandwich filters, also 6½ in. square, were calibrated for luminous directional transmittance; that is, the luminance at 4700 °K of the diffusing component in footlamberts was determined per footcandle of illumination at 2854 °K on the blue glass component. Similarly, the value for luminous directional transmittance thus found is given in the accompanying calibration report. This value is used to compute the luminance at 4700 °K of the light transmitted by the sandwich filter in reflected-light meter calibrations.

The sandwich filters were also tested to assure that under uniform illumination on the blue-glass side, the luminance on the opposite side was uniform over a 6-in. square central area. Each filter was further tested to assure that luminance, as obtained at any angle up to 60 deg from the normal to the filter, was at least 90 percent of the luminance as obtained when viewed along the normal. These tests were made so that the standards could be used to calibrate meters having either large receivers or large solid angles of view.

[1] *These standards are available from the Photometry and Colorimetry Section, National Bureau of Standards, Washington 25, D.C., at $225 a set. To facilitate their use, a report of their design and calibration and directions for their application accompany each set.*

Glass Spheres for Sieve Calibration

Glass spheres for the calibration of sieves number 8 through 18 are now available. These spheres, issued as NBS Standard Sample No. 1019 (price: $9.50), supplement previously issued Sample No. 1017, for calibrating sieves 70 through 270, and Sample No. 1018, for sieves 20 through 70.[1] It is not planned at this time to issue standards for sieves having larger openings

than a number 8 sieve, but standards in the sub-sieve range may be provided in the future.

The glass spheres are used for the routine checking of sieves and for determining the effective sieve opening. In use, the spheres are placed in the uppermost sieve of a series and shaken in exactly the same manner as in a routine analysis. From the weight percentage of spheres that pass through a sieve, together with calibration data provided by the Bureau, the effective sieve opening can be computed. The maximum deviation in repeated calibrations is expected to be less than 2 percent of the nominal width of the sieve openings.

The glass spheres used in the samples were selected from a much larger group, many of which were not spherical. To segregate the round from the out-of-round, the beads were funneled onto a rotating, inclined disk. The spherical beads rolled in a straight line to a collection basket; the others followed a curved path to a discard box.

Polystyrene Molecular Weight Standards

Two molecular weight standard samples of polystyrene are now offered under the standard materials program.[1] These materials, the first molecular weight standards for polymers to be made available, will be useful to chemists in the molecular weight characterization of industrial macromolecular materials used in the production of plastics, rubbers, textiles, and paper.

The samples have molecular weights in the region of 200,000. Sample 705, which has a narrow molecular weight distribution, comes in 2-g lots (price $18), and sample 706, which has a broader molecular weight distribution, is available in 18-g lots (price $12). Each sample is certified for molecular weight and intrinsic viscosity.

The polystyrenes for these samples were prepared and donated to NBS by The Dow Chemical Company. Sample No. 705 was made with a butyl lithium initiator, and No. 706 by a thermal polymerization process. The samples were characterized at the Bureau under the direction of Donald McIntyre of the macromolecules synthesis and structure laboratory.

[1] *A listing of all standard materials issued by NBS can be found in NBS Misc. Publ. 241,* Standard Materials, *available from the Superintendent of Documents, U.S. Government Printing Office, 30 cents. Orders for the samples may be placed with the Standards Samples Clerk, National Bureau of Standards, Washington 25, D.C.*

X-Ray Scattering Data related to properties of the scatterer

QUANTUM THEORETICAL studies of criteria for the derivation and application of approximate wave functions are being conducted at NBS. These studies recently resulted in the development of techniques[1] for obtaining from experimental X-ray scattering data two quantities that are proportional to the values of two properties of the scatterer. These properties were not previously readily susceptible to experimental measurement, but could be calculated by methods involving approximate wave functions. This work, by Jeremiah N. Silverman, of the Bureau, and Yukio Obata,[2] a member of the Japan Atomic Energy Research Institute, therefore provides a basis for estimating the accuracy of such approximate wave functions.

A real need exists for approximate wave functions which yield reasonably accurate values of the properties of polyelectronic atomic and simple molecular systems and yet are of a form sufficiently simple that the calculations remain tractable. Expectation values of properties of a system derived with the use of various wave functions can be intercompared, but a check with corresponding experimental data is more desirable. Application of the techniques developed at the Bureau to systems for which the wave functions are known with sufficient accuracy will help to establish criteria for judging the adequacy of approximate wave functions to be applied to more complex systems.

In the present study, two sum rules were derived that directly relate experimentally obtained coherent X-ray scattering data to two properties of the scattering system. These two properties—diamagnetic nuclear shielding constant and self-energy of the charge distribution of the scatterer—are of theoretical interest and usually have been available only from theoretical calculations. The shielding constant, of importance in nuclear magnetic studies, determines the strength of the opposing field set up by the induced diamagnetic circulation of the electrons when an external field is applied, and the self-energy represents the electronic repulsive portions of the total energy of the system.

The first sum rule states that the integration of the X-ray scattering factor for spherically symmetrical systems over all possible scattering angles yields a quantity directly proportional to the diamagnetic nuclear shielding constant.

The second sum rule, which analogously involves the X-ray intensity for spherically symmetrical systems or for gaseous molecules with random spatial and angular orientation, yields a quantity proportional to the self-energy of the charge distribution of the scatterer.

These two rules provide a new means of checking the accuracy of quantum-mechanical calculations that involve aproximate wave functions.

[1] *For further information, see* Sum rules relating coherent X-ray scattering data to the diamagnetic nuclear shielding constant and to the self-energy of the charge distribution of the scatterer, *by Jeremiah N. Silverman an Yukio Obata, Note, J. Chem. Phys.* **38,** *No. 5, 1254–1255 (1963).*

[2] *Mr. Obata's portion of this work was performed while in residence at Harvard University.*

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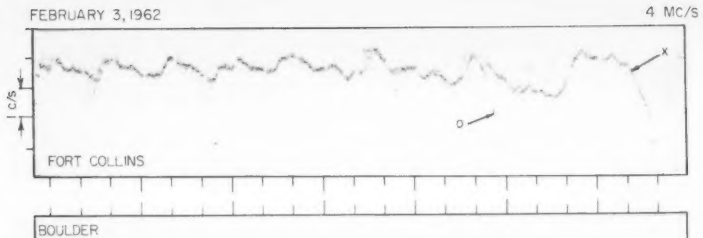
Measuring of Ionospheric Cl by Dopp

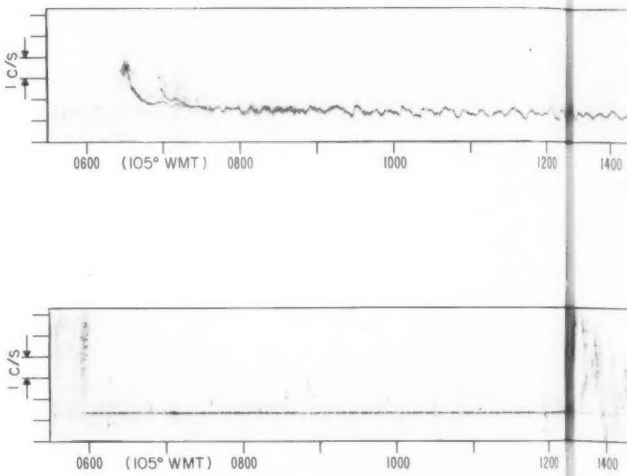


Simultaneous records of the frequencies of signals reflected from moving clouds of ionization, made at two different receivers, show a time displacement of several minutes for the individual disturbances. The location and speed of the ionospheric shift can be inferred from the time displacement. The time displacement is measured by identifying the same event on both traces.

HORIZONTAL MOVEMENTS of clouds of ionization in the ionosphere surrounding the earth are being measured by NBS scientists.[1] The technique of measuring the movements, developed by J. M. Watts and Kenneth Davies of the Boulder, Colo., Laboratories, is based on Doppler changes in the frequency of a reflected radio signal.[2] Movements of ionized clouds have been shown in experimental use of the technique on frequencies of 4 and 5 Mc/s by means of a transmitter and spaced receivers.

The earth's ionosphere is neither homogeneous nor stable, but consists of layers of ionization at various levels which change position from time to time, largely in characteristic daily and seasonal patterns. The NBS Central Radio Propagation Laboratory at Boulder, Colo., has collected ionization and height data from stations in all latitudes for a number of years. Many of these measurements were obtained from the ionosonde, a radar instrument developed by NBS to record distances to the ionized layers in terms of the times taken by radio pulses to travel to the reflecting levels and back, on various frequencies. The ionograms obtained from such an instrument give layer heights sampled at regular time intervals, from which long-term changes, but not short-term variations in height, can be deduced.

A frequency-sensing instrument was devised at the Bureau to supplement ionogram data.[2] It does not measure absolute layer height, but does determine time variations in height by comparison of the frequency of the reflected wave with that from a stable oscillator. Any change in distance is evidenced as a change in an approximately 5-c/s beat frequency, the difference between the received frequency and a stable local oscillator frequency. This 5-c/s sub-audio tone is recorded on slow-moving magnetic tape and analyzed from the audio tone obtained in speeded-up playback. If both transmitter oscillator and receiver reference oscillator are sufficiently stable, the beat frequency will change only with variations in the phase path of the transmission. Changes in the beat frequency can be easily analyzed by conventional audio techniques.



The Bureau has experimented with the Doppler technique using one transmitter and two receivers, one 20 km (12 mi) and the other 70 km (43 mi) away from the transmitter. Transmission at 4.000 Mc/s have been used.[1, 3] Charts transcribed from the magnetic tape recorded at the receivers show only the ground wave (used as the zero-shift reference) during the night because the sky waves then penetrate the ionosphere instead of being reflected. On magnetically "quiet" days the "extraordinary" wave appears near dawn, following the daily increase in ionospheric electron density, and the "ordinary" wave about 30 min later. (The ordinary and extraordinary waves are two mutually independent radio ray components which have different polarizations, and are affected differently by magnetic and ionospheric conditions.) The beat tone then shifts, indicating that the reflection level is descending at about 60 m/sec with the buildup of ionization in the *F*–2 layer of the ionosphere.

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eri Clouds
y Doppler Techniques

The new technique revealed that the reflection levels bob up and down, as indicated by a frequency fluctuation of approximately 0.25 c/s about the means with a period of about 15 min. This motion of both ordinary and extraordinary reflections is very apparent following the much larger diurnal change about 0700, and even during it. The vertical movement of the boundaries is due to the horizontal motion of clouds of electrons (i.e., a corrugated surface). The shift in height was calculated in wavelengths by integrating the rate of change, in which process the shift was approximated by a cosine wave of the same period and displacement: the shift was found to be approximately 2 km (1.2 mi).

The horizontal cloud movements producing the bobbing effect were investigated by comparison of the frequency changes in the signals recorded at the 20-km-distant receiver and at the receiver at Fort Collins, Colo., 70 km from the transmitter at Boulder. A frequency of 4.000 Mc/s was used. Events (marked by identifiable indications on both records) for a sample evening appeared on the Boulder record an average of about 5 min later than on the Fort Collins record. This time lag is equivalent to a drift speed of 420 km/hr for clouds lying between the two receivers and drifting toward one of them.

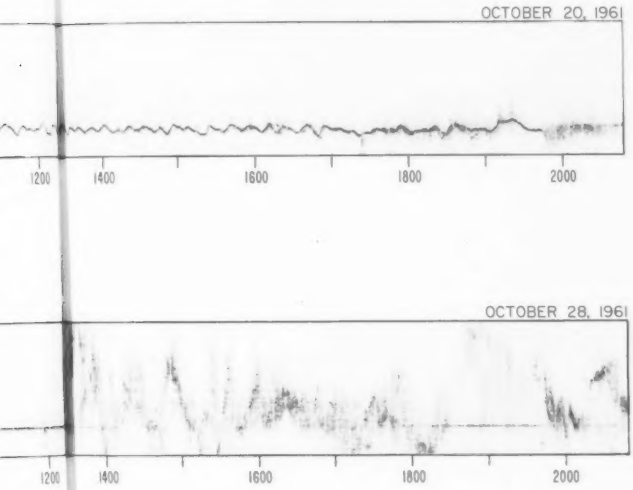
The investigators also estimated the velocity of the electron clouds, by calculations based on cloud sizes and period, to be 330 m/sec (approximately 740 mi/hr), somewhat less than velocities computed by some other researchers. They noted, however, that the actual horizontal motion might be different from that calculated, since the propagation path was probably not parallel with the direction of movement.

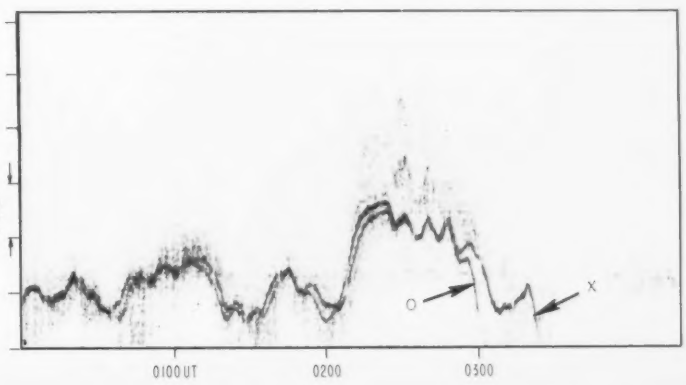
An interesting phenomenon in the records provides additional information about drifts from the ordinary and extraordinary wave reflections. The frequency trace splits into two traces, similar but displaced in time. The ordinary ray is reflected about 16 km to the north of the point of reflection of the extraordinary ray, due to the bifringence of the ionosphere. This splitting usually appears in the late afternoon; its absence earlier may be due to greater absorption of the extraordinary wave, in the *D*-region, near midday.

[1] The measurement of ionospheric drifts by means of a Doppler shift technique, *a letter from K. Davies to the Editor of J. Geophys. Res.* **67**, 4909 (*Nov. 1962*).

[2] Rapid frequency analysis of fading radio signals, *by J. M. Watts and K. Davies, J. Geophys. Res.* **65**, 2295 (*Aug. 1960*).

[3] Doppler studies of the ionosphere with vertical incidence, *correspondence from K. Davies, Proc. IRE* **50**, 94 (*Jan. 1962*).





Above: **Records of frequency changes of radio signals, received in a study of reflection from drifting ionized clouds, show ground wave, used as zero-shift reference, at extreme left. Upper record made on magnetically "quiet" day shows first faint ground wave, extraordinary and ordinary waves settling down to approximately zero change, and then frequency shifts with about a 15-min period throughout daylight hours. Lower record shows loss of reflection and more extreme shifts in height occurring on magnetically "disturbed" day.** *Right:* **Shifting of ionized atmospheric layers above an NBS ionospheric research station at Boulder, Colo., is shown graphically for several hours. The two traces show reflections of the ordinary radio wave (○) and the extraordinary wave (×). Ascent of a layer is indicated by its trace dipping.**

Colorimetric Determination of Plastic Degradation

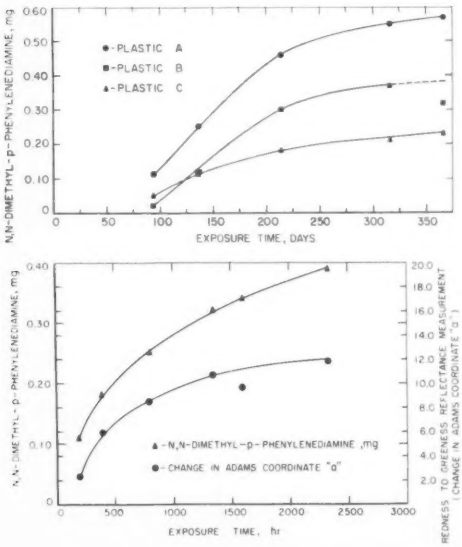
A SENSITIVE colorimetric method for determining degradation of fiberglass-reinforced polyester plastics has been developed at the Bureau.[1] Devised by V. E. Gray and J. R. Wright as part of a program of research on the properties of building materials, this technique provides a rapid, reproducible means for predicting the durability of various polymeric substances.

Fiberglass-reinforced plastics are being employed for many structural purposes today. For example, they are used in skylights, patio roofs, wall panels, and in installations where strong yet decorative and translucent fabrication is required. However, weather exposure decreases their strength and light-transmitting characteristics, and a measure of this degradation is needed to predict durability and to develop improved specifications for reinforced plastic building materials. Measurements of physical properties such as tensile strength and elongation have been employed to evaluate degradation, but significant results have not always been obtained. The present study was therefore undertaken by the Bureau to measure degradation by chemical means.

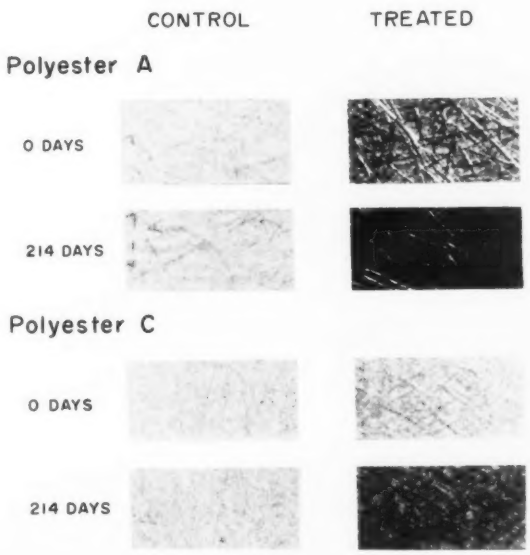
Commercially available plastics approximately 0.16 cm thick were obtained from several manufacturers and were cut into test specimens. Some of these specimens were exposed to natural weathering conditions for periods up to 18 months in an open rack inclined at a 45° angle facing south on an NBS laboratory roof. Others were exposed to carbon-arc radiation in an accelerated weathering machine at 140 °F for periods up to approximately 2500 hr.

After exposure, two different color reactions were used to determine the extent of specimen degradation. In the first reaction, both exposed and control (unexposed) specimens were immersed in a known amount of a diamine, specifically, *N,N*–dimethyl–*p*–phenylenediamine (DMPDA), in a benzene-methanol solution and shaken continuously for two hours. The specimens were then removed from the solution, washed with methanol, and dried.

The DMPDA solution produced little, if any, visual color change in the control specimens, whereas the exposed (and treated) specimens showed pronounced color differences, varying from yellow to brown. Color measurements were made with a tristimulus differential



Top: **Studies of weathered fiberglass-reinforced plastic building materials show that the magnitude of such degradation is related to the quantity of *N,N*-dimethyl-*p*-phenyl enediamine that reacts with exposed specimens.** *Bottom:* **The materials also show good correlation between the quantity of *N,N*-dimethyl-*p*-phenylenediamine reacted with the specimen and the color change in the specimen as determined by redness to greenness reflectance measurements (Adams coordinate *a*).**



Weathered specimens of fiberglass-reinforced plastic building materials treated with *N,N*-dimethyl-*p*-diphenylenediamine showed a yellow to brown color. Discoloration, an indication of degradation, depends on the particular plastic and on the length of exposure.

olorimeter to obtain instrumental color values for each ype of specimen, and the values found for the controls were subtracted from those found for the exposed specimens. The resulting values could be directly correlated with the various exposure periods.

In the second color reaction, aliquots of the solution used to effect coloration in the degraded specimens were treated with benzoyl peroxide to oxidize the unreacted DMPDA. The oxidation reaction produced brightly colored pink solutions, whose intensities increased with the amount of DMPDA present. Intensity values obtained with absorption spectroscopy gave the quantities of DMPDA present in the solutions. When these quantities were subtracted from the known amounts of DMPDA originally present in the solutions, the amounts of reacted DMPDA could be quantitatively determined, and then directly related to the degree of specimen degradation.

Most of the work done at the Bureau thus far has been conducted with polyester test specimens. However, natural and accelerated weathering of several types of commercially available acrylic and polyvinylchloride plastic panel specimens has been started, and colorimetric degradation studies will be extended to include these products on completion of the exposure period.

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[1] *For further technical details see* A colorimetric method for measuring polyester degradation due to weathering, *by V. E. Gray and J. R. Wright, J. Appl. Polymer Sci.* **7**, *No. 3 (1963); also, Division of Organic Coatings and Plastics Chemistry (ACS) preprint (Apr. 1963).*

J. Howard Dellinger

J. Howard Dellinger, internationally known expert in the field of radio research, died December 28, 1962. Dr. Dellinger was formerly Chief of the NBS Central Radio Propagation Laboratory. Allen V. Astin, NBS Director, said, "The National Bureau of Standards has lost one of its most distinguished alumni, and the field of radio and electronics has lost one of its most important pioneers."

Dr. Dellinger, who initiated radio research at the Bureau in 1911, was also known for his work with the national and international conferences on radio problems. He is credited with the discovery of the simultaneous occurrence of solar eruptions and radio effects (the Dellinger Effect). He also made studies of the ionosphere and high-frequency radio propagation and supervised the development of many basic radio aids to air navigation, and the initiation of the U.S. standard-frequency broadcast service (WWV).

In 1907, Dr. Dellinger joined the staff of the Bureau, where he worked on the determination of the conductivity of copper for a few years. He was named chief of the Radio Section in 1919.

During World War II, Dr. Dellinger was selected by the Armed Services Joint Communications Board to direct the work of the Interservice Radio Propagation Laboratory. It was the task of this group to draw together accumulated research knowledge and data from which to make radio propagation predictions for the armed services. In 1946, this organization became the Central Radio Propagation Laboratory, and the prediction service was made available for civilian as well as military use. Dr. Dellinger continued as Chief until his retirement from NBS in 1948.

After retiring from NBS in 1948, Dr. Dellinger continued his work as a radio consultant and adviser. In 1960, he received the twelfth annual Pioneer Award from the IRE Professional Group on Aeronautical and Navigational Electronics in recognition of his basic work on electronic systems for aircraft guidance during approach and landing.

Dr. Dellinger was born in Cleveland, Ohio in 1886. He attended Western Reserve University from 1903 to 1907 and received his bachelor of arts degree from George Washington University in 1908. He was a fellow at Princeton in 1912 and 1913, receiving his Ph. D. there in 1913. He was elected to Phi Beta Kappa at Western Reserve and was presented a Doctorate of Science degree by George Washington University in 1932.

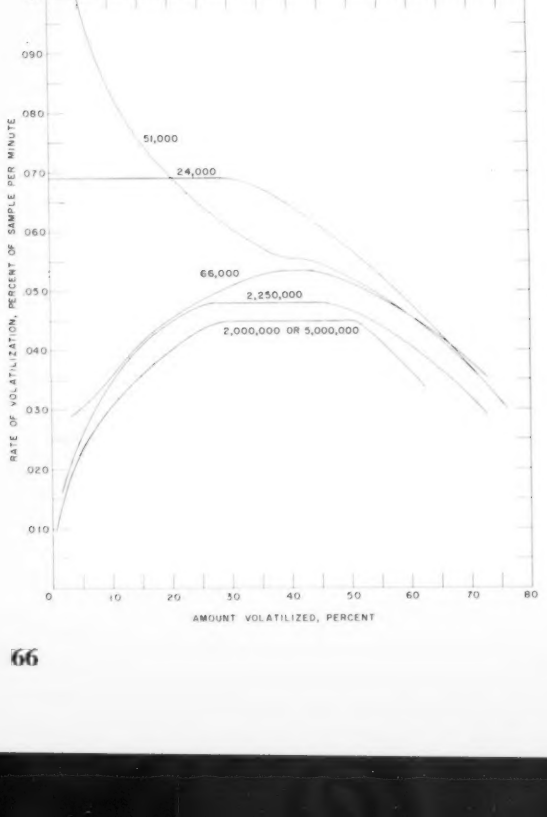
The author of more than 200 papers in his fields, Dr. Dellinger was radio editor for Webster's Dictionary. He was a fellow of the Institute of Radio Engineers (Vice-President in 1924, President in 1925, Medal of Honor in 1938), a member of the Washington Academy of Sciences (Vice-President in 1935, 1939, and 1941), and a member of the International Scientific Radio Union (honorary member for life of the U.S. National Committee, Honorary President for life).

MECHANISM OF POLYSTYRENE DEGRADATION

POLYSTYRENE may be formed in many shapes and used as foams, films, or fibers in a wide variety of applications. However, a better understanding of the mechanism by which this polymer is degraded could lead to many additional uses. To aid in solving this problem, pyrolysis studies of polystyrene fractions in two molecular weight families were recently conducted by S. L. Madorsky, D. McIntyre, J. H. O'Mara, and S. Straus of the polymers laboratory. Their results indicate that polystyrene degradation follows a zero-order reaction; that is, the rate of reaction is a constant unaffected by the concentration of the reactants.[1]

Some polymers, e.g., polytetrafluoroethylene and polyethylene, follow well-defined first-order reactions on degradation. In such cases the rate of reaction is directly proportional to the concentration of the reacting substance. Many polymers decompose at least partially by a first-order reaction. However, previous Bureau studies on the pyrolysis of polystyrene at high temperatures had indicated the reaction might follow a zero-order rate.[2] Therefore the present study was conducted at relatively low temperatures to obtain a more detailed rate curve.

Experiments were carried out with fractionated and unfractionated high-purity polystyrenes of high and low molecular weights. Samples weighing from 4 to 5 mg were pyrolyzed in a vacuum for various time periods at temperatures ranging from 304 to 312 °C. An electronic microbalance automatically recorded the temperature and loss of weight (percent volatilization). Plots of the pyrolysis data were used to elucidate the degradation mechanism.



In the high molecular weight family the unfractionated sample had an average molecular weight of 2,250,000; the high and low fractions had average molecular weights of 5,000,000 and 2,000,000, respectively. Rate curves showed similar results for the three samples. Molecular weight-conversion curves show that initially the molecular weight dropped rapidly but soon stabilized at 40,000 to 60,000. The level of stabilization seemed to be independent of the initial molecular weight or of the molecular distribution in the polymer species provided the initial molecular weight was not below the stabilization level. As generally explained, the initial drop in molecular weight is caused by thermal scissions in the chain forming smaller molecules with free radical chain ends. These smaller molecules decompose by "unzipping" from the free radical end into very small units, chiefly monomers. When the number of chain ends disappearing through unzipping is balanced by the number formed through random scission, a state of equilibrium is established. This condition is shown by a plateau on the rate curve, indicating that the overall degradation reaction is of zero order; i.e., the rate of decomposition is constant. The rate remains constant as long as the number of chain ends stays constant. However, at about 50 percent volatilization the rate of unzipping became greater than the rate of formation of new chain ends and the overall rate decreased.

In the low molecular weight series the unfractionated sample had an average molecular weight of 51,000; 66,000 and 24,000 were the molecular weights of the high and low fractions. As these molecular weights are near or below the stabilization level, the samples would be expected to show little or no stabilization.

The unfractionated polymer (with a molecular weight of 51,000) apparently had a high proportion of very short chains. Initially the rate of disappearance of the chain ends was faster than the rate of formation of

NBS studies indicate that polystyrene degradation proceeds at a zero order rate at sufficiently low temperatures. The rate curves for a high molecular weight family (with molecular weights of 2,000,000, 2,250,000, or 5,000,000) are similar; all show a plateau which is indicative of a zero-order reaction. Thus the degradation proceeds at a zero order when the initial molecular weight is high. The rate curves for the low molecular weight family are all different; the curve for the lower fraction (molecular weight 24,000) is initially flat, indicating a constant rate; the curve for the higher fraction (molecular weight 66,000) shows a maximum; the curve for the sample with molecular weight of 51,000 shows a point of inflection.

new chain ends by thermal scission; thus the rate curve showed a high initial rate followed by a short interval of stability at about 40 percent volatilization.

The molecular weight of the higher fraction (66,000) was in the region at which stabilization occurs. Although the temperature was low enough for a plateau to occur on the rate curve, the stabilization was of such short duration that the curve showed a maximum instead of a plateau.

The low fraction (average molecular weight, 24,000) apparently had a narrow molecular weight distribution and was free of very short-chain molecules. Initially the rate of formation of new chain ends by scission was equal to the rate of disappearance of the chain ends by unzipping. Decomposition proceeded in the manner of a zero order reaction, at a high rate. However, beyond 30 percent weight loss the chain ends began to disappear more rapidly than new ends formed and the rate gradually dropped.

Thus, results indicate that polystyrene degradation proceeds by a zero order reaction at sufficiently low temperatures. However, a comparison of the rate curves of the two molecular weight families shows that the degradation can maintain a high constant value only when the initial molecular weight is high.

[1] *For further technical details, see* Thermal degradation of fractionated high and low molecular weight polystyrenes, *by S. L. Madorsky, D. McIntyre, J. H. O'Mara, and S. Straus, J. Research NBS* **66A** *(Phys. and Chem.), 307–311 (1962).*

[2] Thermal degradation of polymers at low rates, *by S. L. Madorsky, J. Research NBS* **62,** *219–228 (1959).*

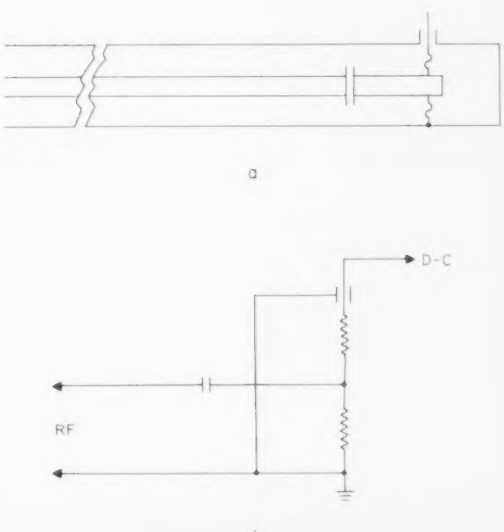
Substitution Error Found in Dual-Element Bolometer Mount

ONE OF THE responsibilities of the Radio Standards Laboratory of the NBS Boulder Laboratories is to strive constantly for greater precision and accuracy in measurements of microwave power. In fulfilling this responsibility, a constant review and examination of current practices and techniques is as important as the search for new measurement methods, and often leads to advances in the state of the art.

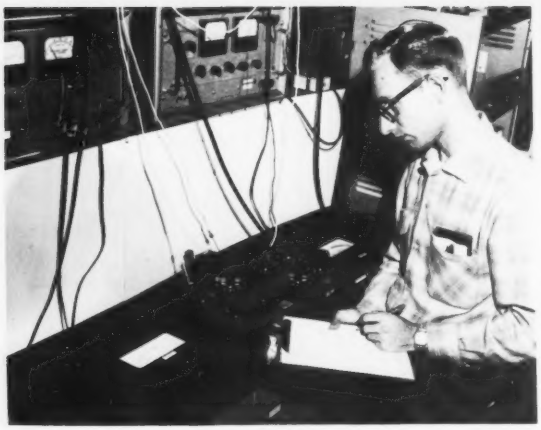
During the past year certain aspects of the bolometric technique of power measurements were extensively investigated, under the direction of Glenn F. Engen, to determine the extent of error involved.[1] The results of this study, which revealed a source of error not formerly recognized, are significant to those who develop or use power-measuring techniques. They are particularly meaningful to manufacturers of microwave power meters and related apparatus, because of certain tolerances which are built into such devices at the time of production.

The bolometric technique of power measurement plays a prominent role in the existing microwave measurements art. In coaxial systems a bolometer mount design is extensively employed which uses a pair of bolometers. As shown in the diagram, the elements are operated in series for the d-c or audiofrequency bias power and in parallel at the UHF and microwave frequencies. The practical advantages which accrue from this mode of operation include a better impedance match with existing bolometer elements and a simplification or avoidance of the problem of providing a d-c return to the center conductor. Unfortunately, this mode of operation also permits a type of substitution error which evidently had not been previously recognized. This error is in addition to, and may be considered an extension of, the substitution error which exists when the bolometer elements are operated individually.

As generally understood, the term "substitution error" refers to the failure of the d-c and microwave powers to produce equivalent changes in bolometer



A previously unrecognized type of substitution error in measurements of dual element bolometer mounts has been found by investigators at the NBS Boulder Laboratories. The drawing shows both a diagram (*a*) and an equivalent circuit (*b*) of such mounts.



F. R. Clague records data during the experimental determination of a type of substitution error in the measurement of dual-element bolometer mounts. The error is associated with unequal division of resistance in the mount.

resistance. This error is possible because the d-c and microwave currents follow different paths in traversing the bolometer element. However, in the frequency region where dual element bolometer mounts are most often employed, the error due to this source is generally believed to be negligible.

Unfortunately, the measurement technique usually associated with these mounts is of such a nature that another type of substitution error is introduced. This error is possible because only the *sum* of the two bolometer resistances is maintained at a constant value. The physical basis for this error will become evident from a review of the bolometric measurement technique.

The bolometer is a temperature-sensitive resistor, operated in conjunction with a bolometer mount which provides the means for coupling to both d-c (or audio-frequency) and microwave energy. The bolometric power measurement consists in observing the d-c power required to heat the bolometer element to a prescribed resistance value both with and without the microwave power applied. To the extent that the substitution process is valid, the difference in these values of d-c power is equal to the microwave power.

In general, the resistance of a bolometer is a function of the total power absorbed and, to some extent, of the manner in which this power is distributed throughout the bolometer element. For a single unit, as noted earlier, a substitution error results if there is a significant difference in the paths followed by the d-c and microwave currents and a consequent difference in power distribution.

Consider now the case where two bolometer elements are employed. In general, the sum of the two resistances will be a function of (1) the total power absorbed, (2) the ratio or manner in which this power divides between the two elements, and (3) the power distribution within the individual elements. This situation differs from the single-element case by the addition of item (2).

The frequency region in which these techniques are generally used also includes the transition region from circuit concepts to the field equations. Although the resultant conclusions cannot be regarded as completely rigorous, a considerable amount of additional insight into this problem is provided by the application of circuit concepts to the bolometer mount.

First, consider the case where the total resistance is brought to the typical 200-ohm value by application of d-c power alone. The series connection enforces the condition that the *currents* in the two elements be equal. However, because of nominal differences in individual characteristics, the resistance division does not in general occur at the exact 100-ohm value. As a result, the power division is also unequal and the *greater* amount is dissipated in the element of *larger* resistance.

Consider next what happens when the microwave power is applied. The parallel connection requires that the RF *voltages* across the two elements be equal and, as a result, the *larger* amount of microwave power will be dissipated in the element of *smaller* resistance.

Announcements of Symposia

A reminder that the **1963 Symposium on Humidity and Moisture—Measurement and Control in Science and Industry** will be held in Washington, D.C., at the Sheraton Park Hotel, May 20–23. The joint sponsors of the meeting are NBS, the Weather Bureau, the Instrument Society of America, the American Meteorological Society, and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

For further information, contact:

Mr. John W. Morgan
Johnson Service Co.
900 N. Stafford St.
Arlington, Va.

A **Symposium on the Ellipsometer and Its Use in the Measurement of Surfaces and Thin Films,** sponsored by NBS, will be held at the Bureau on September 5 and 6, 1963. Papers will cover the state of the art in the application of the Drude technique, by such methods as polarization spectrometry and ellipsometry, to the study of surfaces and thin films. Deadline for submission of titles and 200-word abstracts is May 1.

For further information, contact:

Dr. Elio Passaglia
National Bureau of Standards
Washington 25, D.C.

From the preceding discussion it is thus evident that the boundary conditions, which determine the power division ratio between the two elements, are different for the two sources of power. As a consequence, the application of microwave power is in general accompanied by a shift in resistance division.

If the "ohms per milliwatt" coefficients of the two elements are represented by γ_a and γ_b, the microwave power is given by the equation:

$$P_{rf}=P_{dc}+\left[\frac{1}{\gamma_b}-\frac{1}{\gamma_a}\right]\Delta r$$

where Δr is the shift in resistance division which occurs with the application of microwave power and P_{dc} is the *difference* in the d-c power required to maintain the given total bolometer resistance without and with the microwave applied. That is, P_{dc} is that power which is measured by the usual bolometric technique. If the resistance of element b increases with the application of microwave power, Δr is positive; otherwise it is negative.

Because the usual bolometric technique measures only the first term, this second term $\left[\frac{1}{\gamma_b}-\frac{1}{\gamma_a}\right]\Delta r$, represents an error. This error can be minimized by matching the elements such that (1) the γ's are equal and that (2) an equal division of resistance exists. The effect of condition (1) is evident from an inspection of the equation. The effect of condition (2) is less obvious but it also tends to reduce the resistance change that occurs.

The magnitude of this type of substitution error has been measured for a small number of commercially available bolometers, with the following results:

Thermistors: The (percentage) error was small at low power levels but increased rapidly at higher powers. In the worst case observed the error was about 1 percent at 10 mw and 10 percent at 20 mw. In practice these mounts are usually employed in conjunction with auxiliary instrumentation such that the operation is limited to power levels below 10 mw.

Barretters: The largest observed error was around 1½ percent and increased with decreasing power.

It must be emphasized that the number of bolometers evaluated was much too small to permit a statistical interpretation of the results. However, the data do indicate that further study is warranted.

Perhaps the most disturbing feature of this type of error is its dependence upon power level. In this respect it differs from the mount efficiency and "conventional" substitution errors which, according to available information, are either constant or negligible. Although the problems in calibrating bolometer mounts are such that the bolometric technique is limited to a nominal 1 percent in absolute accuracy, single-element bolometer mounts have found use and evidently provide a much higher degree of accuracy in power *ratio* applications. It is evident, however, that dual element mounts are unsuitable for this purpose. To what extent this phenomenon will be important in more routine application can only be determined from further measurements.

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[1] *For further details, see* The DC–RF substitution error in power measurements which use series-parallel connected bolometers, *by G. F. Engen, presented at the 1962 URSI Fall Meeting, Ottawa, Canada.*

PEER-RATING MACHINE

computes group ratings of individuals

COMPUTER TECHNIQUES have been used at the Bureau to develop a portable peer-rating machine for the U.S. Army Personnel Research Office. Designed by J. P. Nigro, D. C. Friedman, J. R. Park, and W. D. Urban of the data processing systems laboratory, the machine collects ratings made of each member of a group by his fellow members, and computes the average rating for each individual. Groups of up to 20 members may thus be rated on leadership, proficiency in performing a task, or any characteristic amenable to evaluation on a superior–inferior scale. The processing of such data, formerly very tedious despite its elementary nature, has now been reduced to 3 sec per individual rating by the NBS device.

To assist in arriving at capability evaluations for servicemen assigned to certain types of work, the Army has often utilized a questionnaire system in which each member of a group numerically rates the performance of all other members in the group. The average of the individual ratings by peers is regarded by personnel administrators as having a validity far greater than is accorded to the individual ratings forming the source. Development of a machine for automatic computation of peer ratings should make possible much broader application of this technique.

Use of the Rating Machine

The peer-rating machine scores either of two types of ratings: a "rank order" on a most-least scale, or a "graphic" rating in terms of descriptive categories. Each rater makes his assignments on a rating panel by inserting plugs (designating the various members of the group) into receptacles on the panel in the desired order.

If a rank order rating is wanted, the rater places the plug bearing his own name in an "own name" receptacle. He then arranges the others (up to 19) in what he

thinks is the proper order in the receptacles denoting rank between "best" and "worst." In rating proficiency as a cook, for example, he would place the plug bearing the name of the best cook in the group (himself excepted) in the *most* position, that of the poorest cook in the *least* position, and those between in their corresponding receptacle positions.

If a rater is making graphic ratings, he puts his plug in the "own name" receptacle and the other plugs in the receptacles having the appropriate category designations. Seven different designations are available, each one having six receptacle positions. This type of rating is useful where ranking by category is quicker or less confusing; using it, each rater could rate each of his fellows as *good cook, fair cook,* or *poor cook*—to give three of seven possible category designations.

For either mode of operation, the machine produces an average rating for each ratee in succession, after the ratings have been completed, as a digital readout that is accurate to two decimal places.

Operations Performed by the Rating Machine

The peer-rating machine is basically a special-purpose computer that performs only addition and division, the two functions needed to compute means. It consists of three primary functional units: the arithmetic, the control, and the storage unit.

The arithmetic unit is a register to total incoming ratings and to function as the dividend register for the division process. The data are obtained and totaled in binary form, scaled and converted to binary-coded-decimal form, and (after division) decoded for presentation as a rating on the digital display. The rated person's number and the number of participating raters are also given.

The machine's control unit functions as a commutating unit, primarily by means of stepping switches and relays. It supplies controlling signals to the arithmetic unit and regulates transmission of data to the arithmetic unit from the storage unit.

The storage unit actually consists of the 20 rating panels, on each of which a rating of all members (the 19 ratees) of the group can be recorded as plug receptacle positions. Each of the 20 plugs accompanying each panel consists of a miniature 24-contact female connector on which is mounted a passive network of resistors and diodes. The network components are of such values and connected in such configurations that each plug will respond to only 1 of the 20 interrogation signals presented to the panels from the control unit.

Left: **J. E. McNally connects a rating panel** (*foreground*) **to the peer-rating machine via a 20-ft cable and quick-disconnect plugs. Rating computed by the machine for each member of the group represents the average of the ratings given him, as on a *best leader-worst leader* scale, by the rest of the group.** *Below:* **McNally records peer rating computed by the peer-rating machine as J. R. Park watches. In-line digital readout gives the ratee number, the number of raters, and the average of the positions assigned to the ratee by his peers. The operator will obtain the rating of the next ratee following a 3-sec computation initiated by depressing a *RATEE ADVANCE* button.**

J. P. Nigro demonstrates how a subject records his ratings on the peer-rating machine. He has placed the plug representing himself in a dummy receptacle at the extreme lower left, and has placed the plug representing the poorest leader just above it. The best leader is placed at the top of the column, and he is placing the remaining ones between in an order showing his appraisals of their leadership. The unused horizontal rows of receptacles on the rating panel are used in making ratings in up to seven categories. The machine will compute the average of up to 19 ratings, on a rank-order scale or in categories, in 3 sec.

After fabrication and testing, the plug circuitry is encapsulated in place in epoxy resin, with a write-on plate bearing the plug identification number on the surface opposite the plug.

The position in which each plug has been inserted (rank position 1 through 19, or category 1 through 7) is coded by making connection with only certain of the contacts of each receptacle. Each member of the rating group is assigned a plug number; he can identify the other plugs by reference to a numbered list of members or by writing the name of each member on top of the proper plug and erasing it after use.

The names on the tops of the plugs aid the rater to arrange and rearrange the plugs in an order corresponding to his rank assignments. Changes in order can be made as often as the rater desires; when the names are arranged to his satisfaction the rater signifies this by folding his rating panel closed, like a book. A panel light on the control console indicates when all raters have signified completion; the console operator then presses a *RATEE ADVANCE* button to obtain the first rating and again to obtain each following one.

The design of the peer-rating machine incorporates provisions for future expansions of its capabilities. Not only can the machine be expanded, with some changes in circuitry, to accommodate 28 persons in each rating group, but it is already wired to permit its use with four groups of 20 subjects each, who could thus make their selections simultaneously. Only the installation of additional panel connectors is needed to take advantage of the latter feature.

The machine as it now exists can, with some minor circuit and connector additions, provide a digital output suitable for operating a tape punch or printer. This modification would not only simplify operation of the equipment, but permit its use in the fully automated data-handling systems of the future.

Publications of the National Bureau of Standards

Periodicals

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Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, $2.25; foreign, $2.75.

Section D. Radio Propagation. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

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